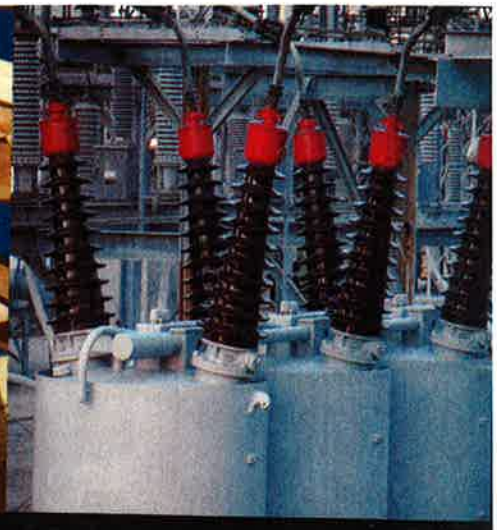


UNIT 34

Installing Branch Circuits

OBJECTIVE

To run wires and safely install boxes, switches, outlets, and fixtures.

Competencies to be developed

After studying this unit, you should be able to:

- Select electrical boxes, outlets, and switches.
- Install and replace switches, outlets, and fixtures.
- Install, extend, and modify branch circuits.
- Test electric circuits.

MATERIALS LIST

- Hand tools suitable for electrical wiring
- Cable ripper
- Wire stripper
- Test light
- 14-2 cable with ground
- 14-3 cable with ground
- Two switch boxes
- One octagon box
- One single-pole switch

TERMS TO KNOW

- new work
- fixture
- wire nuts
- receptacle
- switch
- duplex (double) receptacle
- splitting the receptacle
- single-pole switch
- knockout
- ground (gee) clip
- continuity tester
- continuity
- three-way switch
- common terminal
- switching (traveler) wires
- four-way switch

MATERIALS LIST

- Two three-way switches
- One porcelain lamp holder
- One duplex receptacle
- Two switch covers
- One outlet cover
- Wire nuts
- Ground (gee) clip
- Electrical tape

A knowledge of electrical principles and wiring materials is important. The rules for the proper and safe installation of electrical devices and circuits given in the current National Electrical Code must be strictly observed at all times.

Cable and conduit are run through the floors, ceilings, and partitions of new buildings during construction. Such installations are called **new work**. Electrical codes may permit wiring to be placed in view in old work installations. This is due to the difficulty of concealing wires after a building is completed. In surface installations, however, the wiring must be protected from mechanical damage.

Utility buildings and other farm structures generally do not have finished interior walls. Such structures are relatively easy to wire at any time. However, the National Electrical Code has established special requirements for such wiring.

THE ENTRANCE PANEL

Electricity enters a building by way of an entrance panel (also known as a load center) (Figure 34-1). As discussed in Unit 33, large cables bring electricity from the transformer to the entrance panel. If the cables come in from underground, they are attached to the meter base, which is then connected by cables to the entrance panel. Overhead cables attach to cables that run through the entrance head.

Entrance panels come in different sizes, depending on the amount of current that will be distributed from the panel. The panel consists of large main breakers (where all electricity to the building can be cut off), metal bars for attaching the breakers, and grounded strips. The large entrance cables from the meter usually attach at the top of the panel. Two hot wires bring in 120 volts each. Combined they can create a 240-volt circuit. The grounding bars are attached to a metal rod that is driven deep into the ground to ground the circuit.

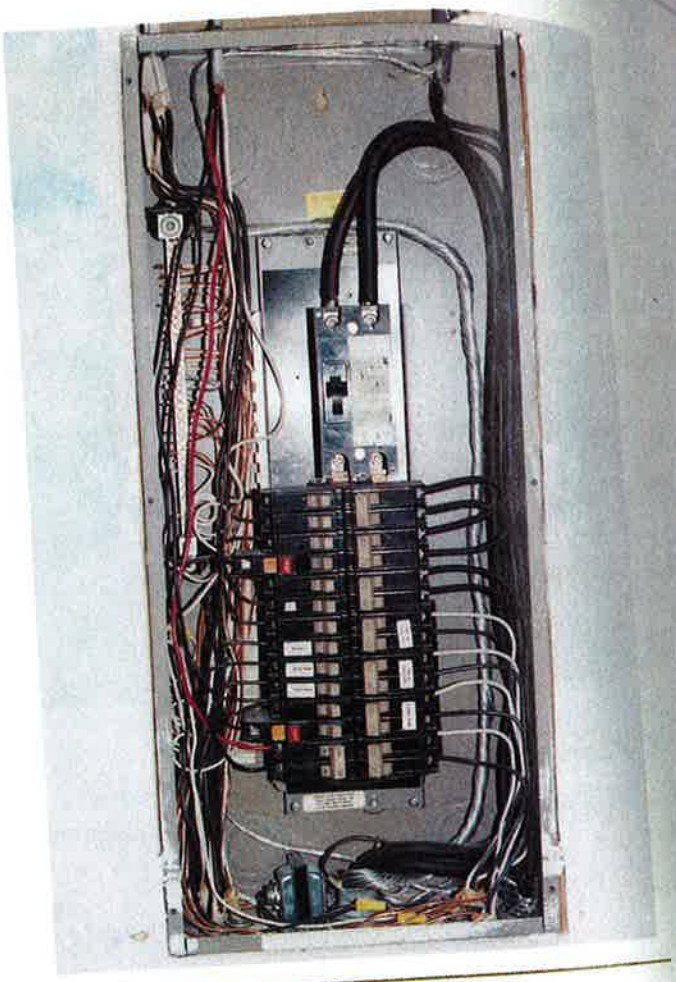


Figure 34-1 Typical service entrance panel.

As each new circuit is attached to the entrance panel, a circuit breaker is attached to the bars that are connected to the entrance hot wires. A black and/or a red wire is attached to the circuit breaker. The neutral wire (white) is attached to the neutral grounding bar, and the bare or green wire is attached to the equipment grounding bar. These bars are then attached to the metal grounding rod that is driven into the ground. This provides power for various branch circuits throughout the building.

WIRING BOXES

All wiring systems require the use of fuses or circuit breakers, and protected wires and boxes. The boxes are metal or plastic (Figure 34-2). Boxes have several important functions:

- They hold the cable or conduit so stress cannot be placed on the wire connections.
- They are nailed, screwed, or clamped to the building to support switches, outlets, or fixtures. A **fixture**

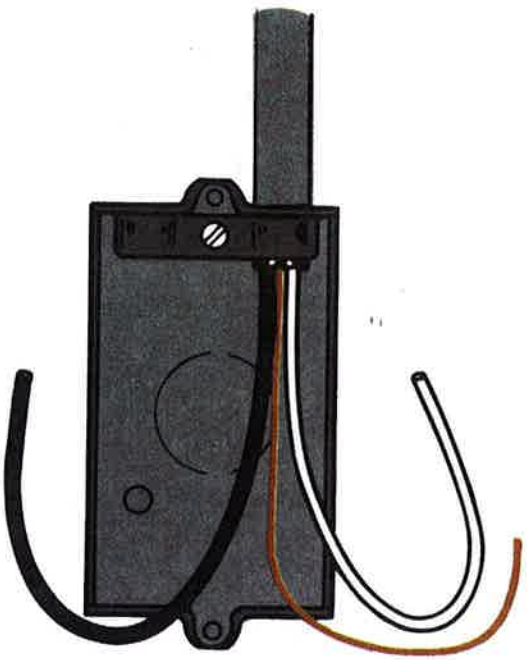


Figure 34-2 All wiring systems require the use of boxes.

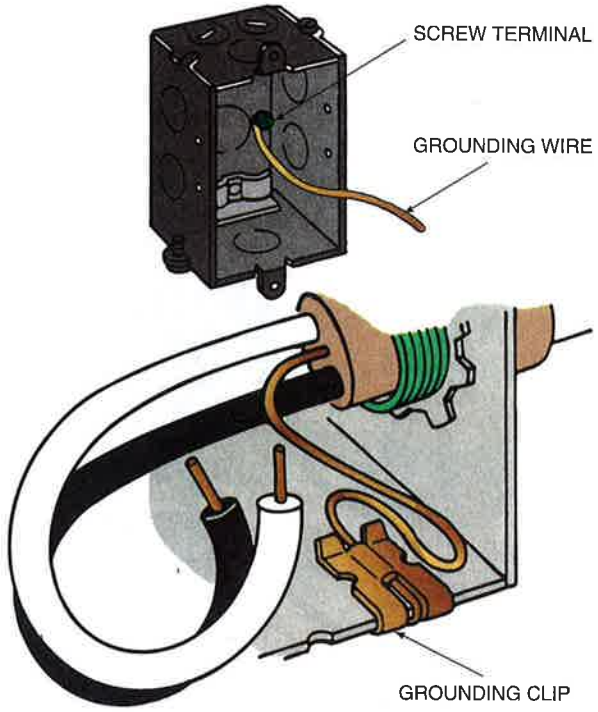


Figure 34-3 A screw or grounding clip is used to attach a ground wire to a metal box.

is a base or housing for lightbulbs, fan motors, and other electrical devices.

- They contain all electrical connections that are not made inside fixtures.
- They prevent mice and other vermin from nesting around electrical connections.

Electrical boxes are available in rectangular or octagonal shapes and in various depths. Some switch and outlet boxes have removable sides so that the boxes can be installed in gangs (series). Such boxes can hold multiple switches or outlets.

Large steel boxes are used for service entrances. They contain the main fuses or circuit breakers. They also contain fuses or circuit breakers for one or more branch circuits.

Certain basic rules apply to wiring all electrical boxes. The National Electrical Code and local building codes must be checked for specific regulations. Some basic requirements follow:

- The box must be fastened securely to the building.
- The cable or conduit must be clamped securely to the box.
- Cables running from box to box must run through the interior of the building's walls, floors, and ceilings, be secured by staples or clamps near each box, and be secured as needed to prevent the cable from being accidentally caught and pulled.
- The box must be grounded if it is metal. The ground wire from the cable is attached to the box by a screw or by a grounding clip (Figure 34-3).
- Wires in boxes must be connected to each other by insulated solderless connectors called **wire nuts**. Bare areas are not permitted on wires except ground wires.
- Ground wires must be held together by a special metal clamp or a solderless connector.
- Wires must be attached to terminals of switches and receptacles by tightening no more than one wire under one screw or spring clamp. A **receptacle** is a device for receiving electric plugs. A **switch** is a device used to stop the flow of electricity. If the receptacle or switch is equipped with special clamps, one wire may be inserted into each clamp provided.
- Positive or hot wires (black, red, or blue) must always be attached to brass-colored screws. Neutral wires (white) must always be attached to aluminum-colored screws. Ground wires (bare or green) are attached to green screws.
- When a white wire must be used as a positive wire (as in a light switch), the insulation visible in the box should be painted black or marked with black tape.

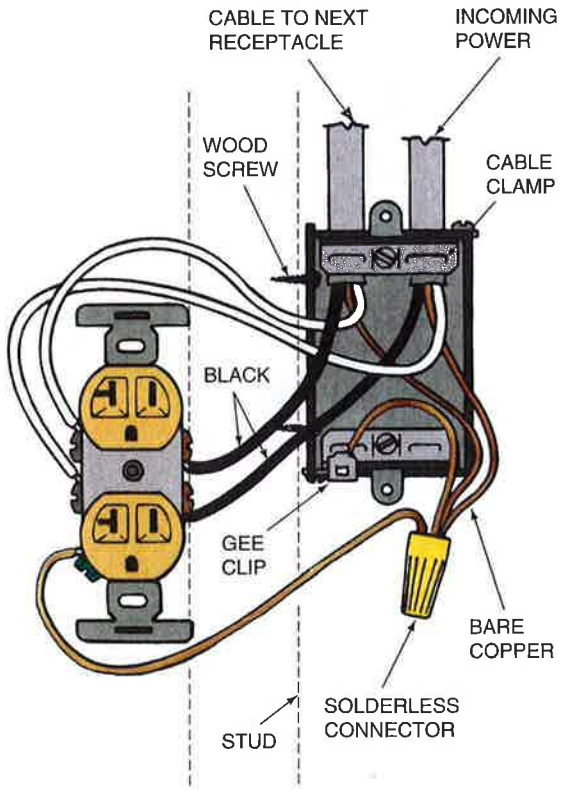


Figure 34-4 Typical duplex receptacle. *(Courtesy of the Pennsylvania State University, Department of Agricultural Education)*

The most common type of receptacle is the **duplex (double) receptacle**, which is wired so that both outlets are on the same circuit (Figure 34-4). The current comes in on a black wire, flows from one screw through a metal strap to the other screw, and, when so wired, continues on to the next electrical box. The two receptacles in the duplex may be wired to two different circuits if the metal strap between the two screws is removed. This is called **splitting the receptacle.**

A standard switch box will only hold four wires safely. To determine the number of wires in a box, only the positive and neutral wires are counted, not the ground wires. In other words, one incoming cable with a black wire, a white wire, and a ground wire is counted as two wires. With an identical cable taking the current on to the next box, the total of four wires has been reached.

WIRING A SWITCH AND LIGHT

A switch is a device used to stop the flow of electricity. A **single-pole switch** is a switch designed to be the only switch in a circuit. The cable carrying current from the service entrance panel may come to an outlet box where a light is mounted or to one where a switch is mounted. For example, a power cable coming to a box where a light is mounted and controlled by a single-pole switch is shown in Figure 34-5. To wire this circuit, a cable with a white wire, a black wire, and a ground wire is used.

The cable is prepared for insertion into the box by slitting 6 to 8 inches of the outside cable covering with a cable ripper (Figure 34-6).

CAUTION!

Care must be taken to prevent damage to the insulation on the individual wires.

The wires are then separated from the jacket and the excess jacket material is cut off.

Electrical boxes are provided with a **knockout**, or partially punched impression, that can be punched out and removed. The cable is pushed through this hole. Some boxes have cable clamps provided with the box; others require the addition of a cable clamp, as illustrated in Figure 34-5. The cable is inserted until 1/16 inch of the cable jacket extends beyond the clamp. The clamp is then tightened, and cable is run between the switch box and the light box. If there is more than one light in the circuit, a cable may be installed to carry current from one light box to the next. All cables must be clamped securely in the boxes and stapled or clamped to the structure within 12 inches of each box, at intervals of 4½ feet or less.

To install the switch, a wire stripper is used to remove about ¾ inch of insulation from the ends of individual wires (Figure 34-7).

CAUTION!

Care must be taken not to nick the wire during this procedure.

A round loop is then made in the end of each wire. Each loop is wrapped around a brass-colored screw in the direction (clockwise) the screw turns when being tightened. The screws are then tightened securely.

Switches are placed in hot wires only—never in neutral wires. Thus a piece of black tape is placed on the white wire to mark it as a hot wire. The ground

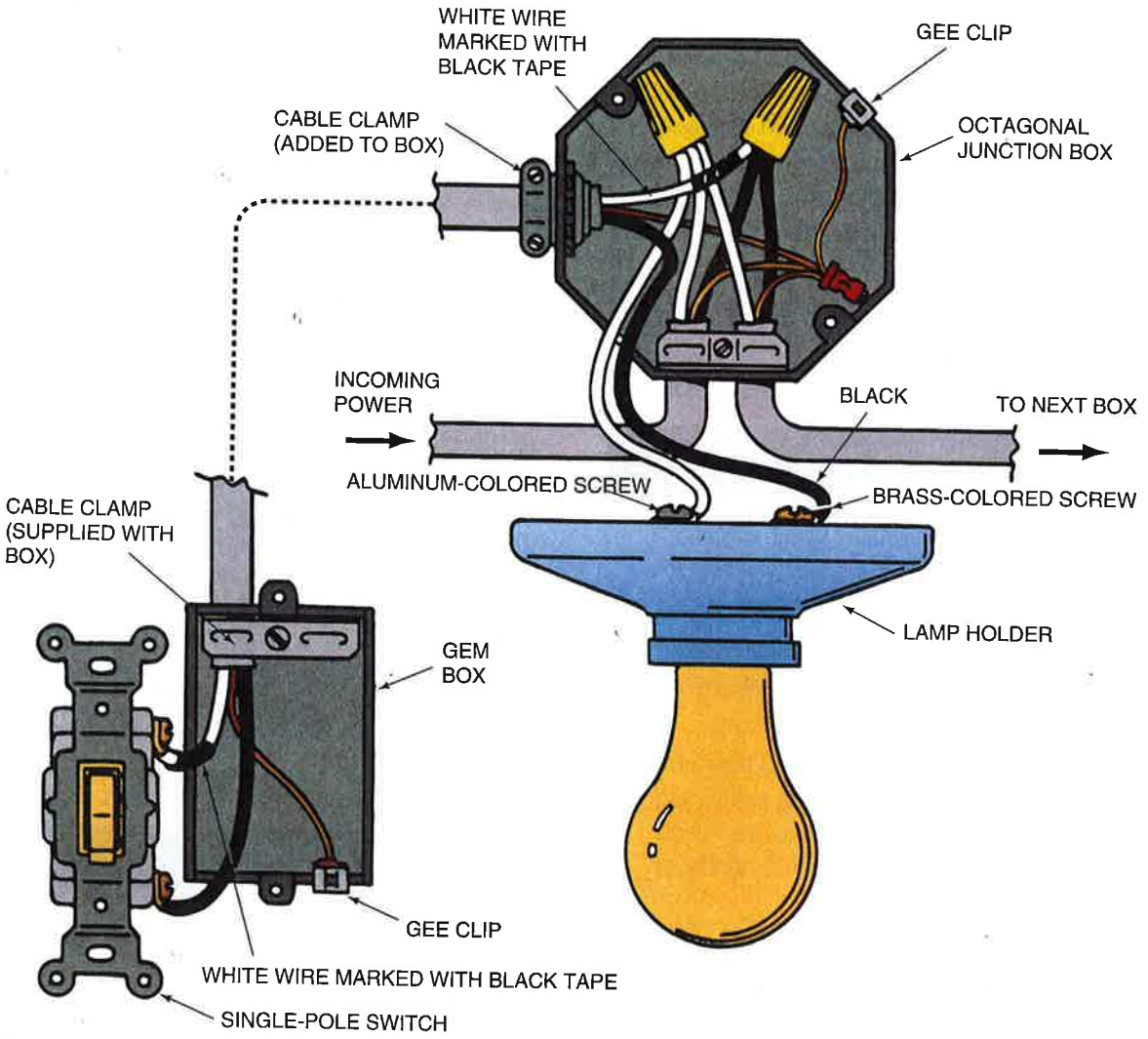
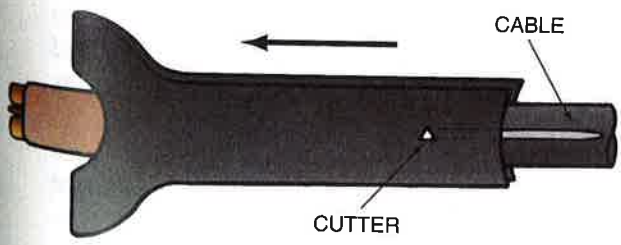
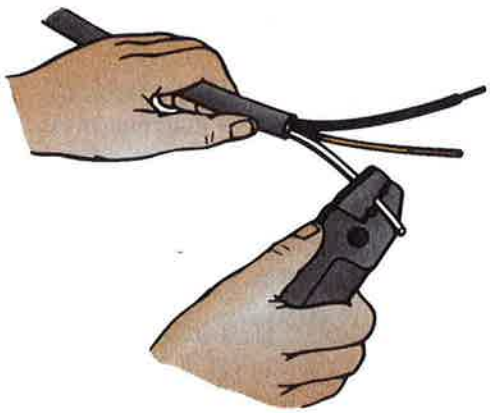


Figure 34-5 A light fixture controlled by a single-pole switch. *(Courtesy of the Pennsylvania State University, Department of Agricultural Education)*



SPLITTING CABLE WITH CABLE SPLITTER

Figure 34-6 A cable splitter is used to cut a slit 7 inches long in the outer covering of nonmetallic sheathed cable. The individual wires are then pulled out of the jacket, and the loose jacket is cut off and discarded.



USING A WIRE STRIPPER

Figure 34-7 When preparing the ends of wires for screws, the electrician must remove ¾ inch of insulation without nicking the wire. Only ⅝ inch of insulation should be removed for wire nuts.

wire is attached to the metal box with a **ground (gee) clip**. The switch is then screwed in place and a switch cover is installed. Some modern installations make use of plastic boxes that do not need to be grounded since plastic is an insulator. The ground wire is attached to the green grounding screw and is not connected to the box.

Wiring the lamp holder box is more difficult. However, the work progresses in a logical sequence according to the following procedure.

PROCEDURE

1. Strip the ends of all insulated wires, leaving ⅝ inch of wire exposed. The wires are now ready for connection with wire nuts.
2. Strip ⅝ inch from both ends of an 8-inch length of bare wire, and ground it to the box with a ground clip or screw.
3. Hold the four ground (bare) wires so they form a bundle. Twist a wire nut onto the bundle and tighten it as much as possible with the hands. For large bundles, use a wire nut handle or pliers to tighten the wire nut.
4. Mark the white wire coming from the switch with black tape. This is now regarded as a black wire.
5. Attach the black wire from the switch to the brass terminal of the fixture or lamp holder.
6. Cut an 8-inch piece of white wire and strip ⅝ inch of insulation from each end. Attach one end to the aluminum-colored screw to the lamp holder.
7. Select and use a wire nut of the correct size to connect the loose ends of the three white wires.
8. Use another wire nut to connect the ends of the three remaining black wires. Treat the white wire with the black tape as a black (hot) wire.
9. Check each connection for tightness by holding by way of the white wire marked with black tape. If the switch is in the "on" position, the current flows through the switch and through the black wire to the lamp holder. Current flows through the bulb and back to the service entrance box by way of white (neutral) wires.

TESTING A CIRCUIT

After all lights and switches are wired, a circuit should be tested before turning on the circuit breaker or inserting the fuse. Use a continuity tester to be sure the circuit is not open. A **continuity tester** is a device used to determine if electricity can flow between two points. **Continuity** means connectedness. A circuit is open if there is a break or poor connection anywhere in it. The circuit should also be checked for shorts, or places where current can get from the black wires to the ground wires or boxes, or where it can bypass the bulb and flow directly to the neutral wires. The final step is to test all boxes to ensure that they are properly grounded.

The following procedure describes how to test a circuit.

PROCEDURE

1. Place all switches in the "on" position.
2. Remove all bulbs.
3. Test the circuit by connecting to the wires at the fuse box or circuit breaker box before the cable is wired into the fuse block or circuit breaker. Using an ohmmeter, touch one lead to the black wire and the other to the white wire of the cable. There should be no reading. This indicates no continuity. That is, there are no points where electricity can flow from the black wires to the white wires.
4. Install a good lightbulb in the last fixture of the circuit. Repeat the test in step 3. There should be continuity through the filament of the bulb, as indicated by a meter response. This indicates that current can flow through all black wires, through the bulb, and back through the

STUDENT ACTIVITIES

1. Define the Terms to Know in this unit.
2. Wire a circuit with an outlet.
3. Wire a circuit with several outlets.
4. Wire a circuit with a light and a single-pole switch.
5. Wire a circuit with a light and two three-way switches.

RELEVANT WEB SITES

http://doityourself.com/electric/

http://www.expertvillage.com/video-series/390_wiring-electrical-outlets.htm

http://www.hammerzone.com/archives/elect/panel/breaker/install.htm

http://www.wikihow.com/Wire-a-Simple-120v-Electrical-Circuit

http://www.acehardware.com/sm-installing-or-replacing-electric-switches--bg-1284746.html

SELF-EVALUATION

A. Multiple Choice. Select the best answer.

1. All electrical connections in a circuit are made
   a. in boxes or fixtures
   b. by screws
   c. with solder
   d. with tape
2. All metal electrical boxes must
   a. be grounded
   b. be securely fastened
   c. secure the cable or conduit
   d. all of these
3. Neutral wires are attached to screws colored
   a. white
   b. green
   c. silver
   d. yellow
4. The device that receives electrical plugs is a
   a. box
   b. cap
   c. circuit breaker
   d. receptacle
5. White wires used as positive wires must be
   a. connected to black wires
   b. connected to fixtures
   c. stripped of all insulation
   d. taped or painted black
6. A properly wired circuit will be
   a. grounded
   b. open
   c. shorted
   d. all of these
7. In three-way switch circuits, electricity passes from one switch to the other through
   a. traveler wires
   b. neutral wires
   c. common terminals
   d. none of these
8. Three-way switch circuits usually include
   a. two-wire cables
   b. three-wire cables
   c. grounded boxes
   d. all of these

B. **Matching.** Match the items in column I with those in column II.

Column I

1. old work
2. duplex
3. solderless connector
4. switch
5. positive or hot
6. red wire
7. neutral wire
8. circuit protector
9. electrical contact
10. switching wire

Column II

a. used in place of black wire
b. always white
c. traveler
d. fuse
e. extensions to existing systems
f. receptacle
g. continuity
h. stops current
i. black wire
j. wire nut

C. **Completion.** Fill in the blanks with the word or words that make the following statements correct.

1. Rules for the proper and safe installation of electrical devices and circuits are given in the _____ _____ _____.
2. All wiring systems require the use of _____ or _____ _____ and protected wires and boxes.
3. A standard switch box will hold _____ wires only, not counting _____ wires.
4. Switches are placed in _____ wires only—never in _____ wires.
5. Black and red wires are generally used as the _____ wires in a three-way switch circuit.

D. **Brief Answer.** Briefly answer the following questions.

1. What does the entrance panel consist of?
2. What is "splitting the receptacle"? What does the operation require?
3. All wiring systems require the use of boxes. What are their four functions?
4. What is a continuity tester used for? When should it be used?